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The Distribution and Growth of Juvenile Salmon and Trout in the Major Tributaries of the River Dee Catchment (Grampian Region)

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The Distribution and Growth of Juvenile Salmon and Trout in the Major Tributaries of the River Dee Catchment (Grampian Region)

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Introduction

The Scottish Office Agriculture and Fisheries Department has maintained facilities for studying the biology of salmonids in the River Dee for many years. Research has been performed at a number of locations where trapping facilities were constructed. The most important of these were those established on the Girnock Burn, completed in 1966. Much has been gained in understanding the mechanisms of smolt production and stock-recruitment at this site.

In 1988, the scope of the work on the River Dee was expanded by the construction of trapping facilities on another tributary, to be examined in parallel with the Girnock Burn. Upstream and downstream traps were constructed on the Baddoch Burn in the western end of the catchment, 25 km up stream of the Girnock traps. These traps are also being run continually, catching all adults moving up stream in autumn and all juveniles moving down stream in both autumn and spring. In addition to comparative biological work between the traps, it was intended to study the genetic character of the stocks and their possible manipulation.

The work at both facilities has the limitation that it examines populations at single sites. It is known that differences in water chemistry in a river system, owing to agricultural activities or to catchment geology and the altitude of juvenile rearing grounds, are important in determining the growth rate of the Atlantic salmon. In addition, increasing interest has been shown in the concept of "Fish Stock", of which there may be several in the Dee system, as a component in fisheries management (Power, 1981). For example, there is evidence to suggest that important characteristics of populations, such as growth rate (Naevdal *et al.*, 1976, 1977, 1978) and time and age of smolting (Refstie *et al.*, 1977) are influenced by the genotype. The diversity of salmon phenotypes observed in different tributaries results from both genetic and environmental influences. This report deals with the latter. It is important that the valuable work carried out at the fixed sites is set against a knowledge of the whole catchment. There is much historical information about the numbers and distribution of adult salmon in the River Dee system (Dee District Salmon Fisheries Board Inspector's Reports). However, there is little information concerning juvenile salmon and trout. This report is intended to rectify that deficiency and create a background for future work. The distribution of juvenile salmon and trout is described, illustrating the influence of altitude, geology and water chemistry on growth and subsequent salmon smolt production.

Description of the Area

The River Dee is relatively free from industrial pollution and runs in catchment with a varied geology. It shows a wide range of wate chemistries. It is approximately 100km long and rises close to Ben Macdu in the west. It flows first south and then eastwards through moorland. Her the major activities are deer stalking, grouse shooting, sheep farming, tourism and salmon angling. At lower altitudes, firstly in the valleys and the more generally, the land is cultivated on fluvioglacial terraces as the rive runs towards the North Sea (Black, 1985; Smith, 1985). Figure 1 shows th physical character of the Dee valley.

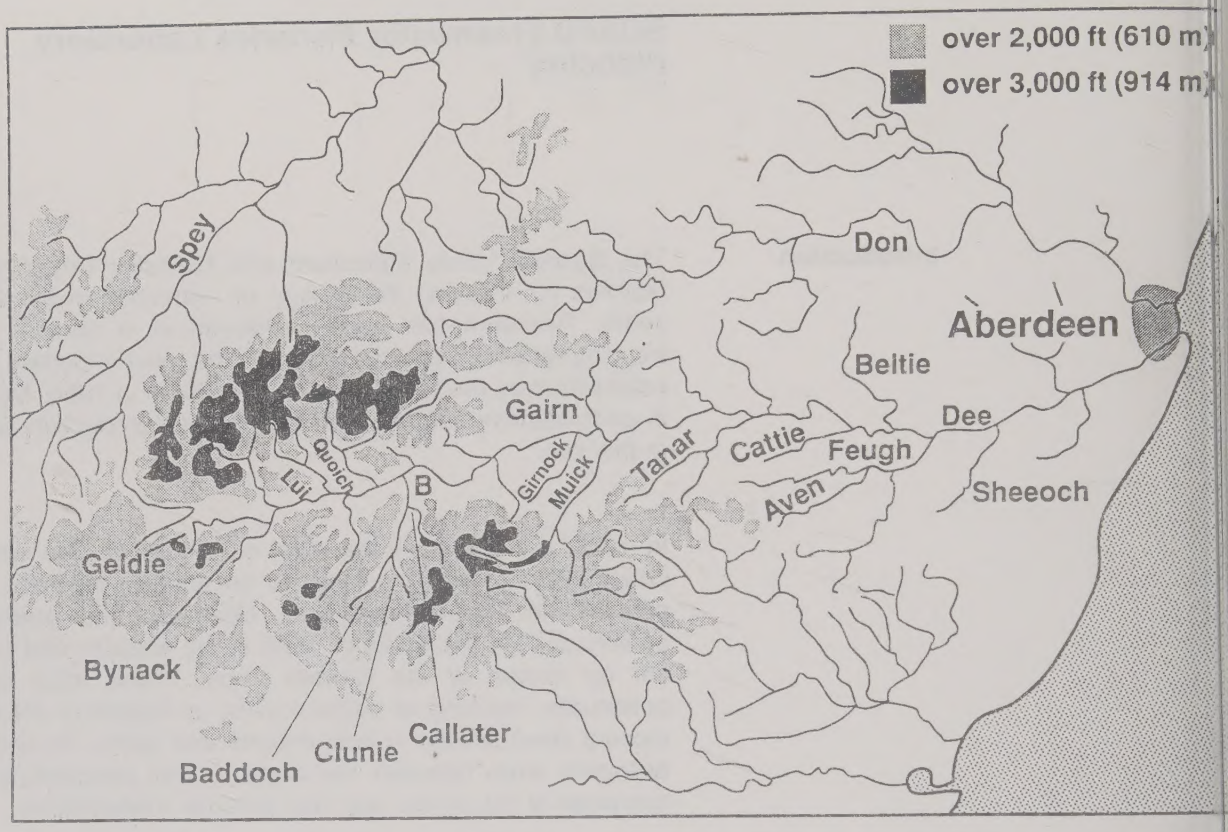

Figure 1. **Physical character of the Dee valley. B indicates the position o Braemar.**

The geology and agricultural development of the catchment influences the water chemistry of the streams draining it. This, in turn, influences the rates of decomposition and fish food production within the streams. Table I shows average values of alkalinity, conductivity and nitrate concentration of the drainage water. The values are the average of four samples taken at different times of the year to even out the changes in water chemistry owing to fluctuations in water level and flow. Figure 2 shows the distribution of the important rock types within the Dee valley. A band of limestone separates off the top end from the main part of the river system. The streams draining the limestone (Baddoch and Clunie) have high alkalinities in the range of 394-416 μeq Ca^{2+} l^{-1}. About 52% of the Dee catchment is composed of granite. Streams with extensive drainage systems on this rock contain water of low alkalinity from 95-209 μeq Ca^{2+} l^{-1} (Tanar, Muick, Aven and Feugh). To the south-east of the limestone are the Dalradian rocks. These produce stream water of slightly higher alkalinity in the region of 298-344 μeq Ca^{2+} l^{-1} (mid and lower Gairn). To the north-west of the limestone the rock is Moine schist generating stream water of intermediate alkalinity between the granite and the Dalradian catchments. In the streams at lower altitude at the eastern end of the catchment, agricultural input (in the Beltie Burn for example) increases the alkalinity despite the granite catchment. A geological and geomorphological description of the Dee catchment is given in Bremner (1912) and Johnstone (1966).

Table I **Water chemistry of the tributaries and main river of the River Dee system. Mean of four samples: September 1988, April 1989, July 1989 and September 1989**

Stream	Altitude (m)	Alkalinity (μeq l^{-1})	Conductivity (micro siemens)	Nitrate (μeq l^{-1})
Park Bridge	30	211	55	76.0
Beltie	75	605	170	105.5
Sheeoch	93	356	105	58.3
Cattie	93	301	76	55.7
Aven	95	67	41	3.0
Aboyne Bridge	130	175	44	7.3
Feugh	170	209	57	15.3
Tanar	150	161	45	4.3
Muick	200	146	36	4.7
Girnock	240	345	67	2.0
Callater	400	283	44	5.0
Clunie	410	416	62	2.3
Baddoch 1	450	394	55	2.3
Baddoch 3	435	407	56	2.0
Baddoch 7	415	395	55	2.0
Gairn 1	440	160	35	2.3
Gairn 2	332	298	52	2.0
Gairn 3	240	344	59	3.3

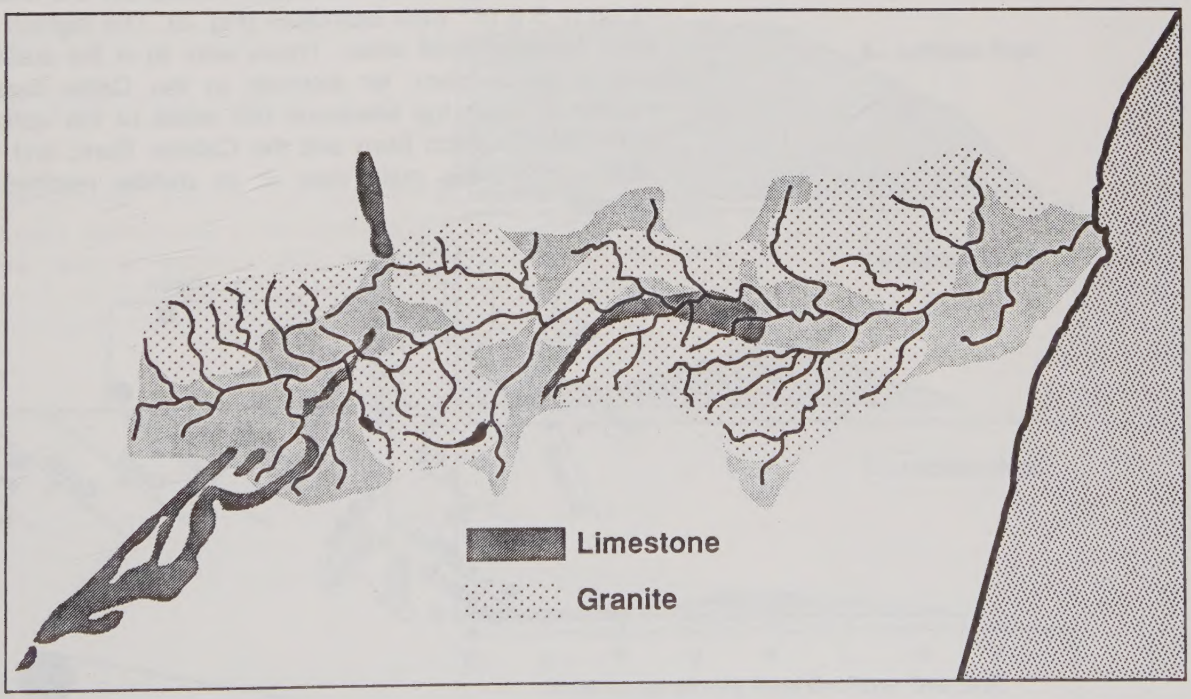

Figure 2. **The distribution of granite (acid) and limestone (basic) rocks within the River Dee catchment.**

Methods

Fish population densities were measured at 65 sites in 18 of the mai tributaries of the Dee river system over a period of two years. The gri references of these sites is given in the appendix. Fish samples wer collected with a 600 watt petrol driven electro-fishing apparatus. The fishin procedure was that described in Egglishaw and Shackley (1977) except tha stopnets were not used in streams over 5m in width. Electro-fishing at eac site was carried out in an upstream direction. Usually a minimum of thre repetitive fishings were carried out at each site per visit. Fish wer anaesthetised in MS222 and the fork length of each fish was measured t the nearest mm. Age classes were separated by size distributio corroborated by scale analysis. The population density of each age clas was estimated by the maximum likelihood method (Zippin, 1956).

Sample sites were chosen using an 1:25,000 OS map. Final choice an measurement of sites were made in the field. These included a site on eac of the River Gairn and Beltie Burn which had been previously visited b W.R. Gardiner in 1987 in general survey work in Scotland. The altitude o the sample sites ranged from 57m on the Beltie Burn, about 20km up stream of the river mouth at Aberdeen, to 595 m on the Baddoch Burn about 95 km up stream from the river mouth. Site areas ranged from 45m² to 138m². Sites were positioned in such a way as to incorporate the majo characteristics of the stream such as pools and riffles typical of the area chosen.

Results

The mean length of each age class was calculated for both salmon an trout. These were converted into weights using summer weight/length data obtained previously from the Shelligan Burn, an index stream in the River Tay catchment – a tributary of the River Almond at an altitude of 150m. The biomass (g m^{-2}) of each age class was calculated as the product of the mean weight and fish density. Fish abundance was expressed in terms o total biomass of all age classes at each site. Biomass was used because o the differing number of age classes present at the sites.

Fish Distribution

Salmon were generally distributed throughout the river system. Biomasses of up to 5 g m^{-2} were estimated (Fig. 3). The highest densities of juveniles were found in three areas. These were a) in the arable area at the eastern end of the system, for example in the Cattie Burn and in the Feugh tributaries; b) in the limestone rich areas of the upper river, eg in the Ey Burn, the Baddoch Burn and the Callater Burn; and c) in the River Gairn which enters the main river in its middle reaches immediately above Ballater.

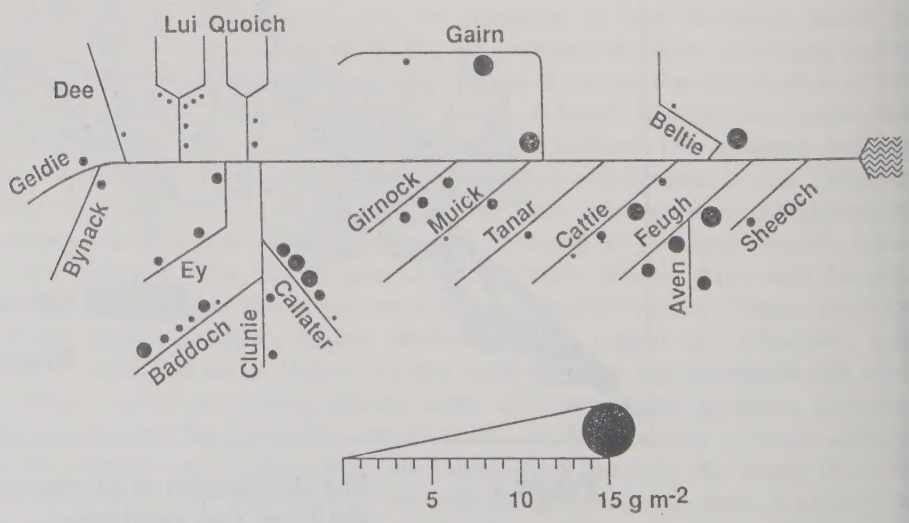

Figure 3. **Biomass of salmon in the River Dee system.**

Trout were abundant in only three of the tributaries, all of which were within 50km of the river mouth at Aberdeen (Fig. 4). Estimates of length and weight in May indicated trout biomasses of up to 10 g m^{-2} in the Beltie Burn. This compares with an average of 12 g m^{-2} in the Shelligan Burn on the Tay, which is considered to be well stocked with salmon and trout. In the rest of the Dee river system, trout biomasses were usually less than 1g m^{-2}.

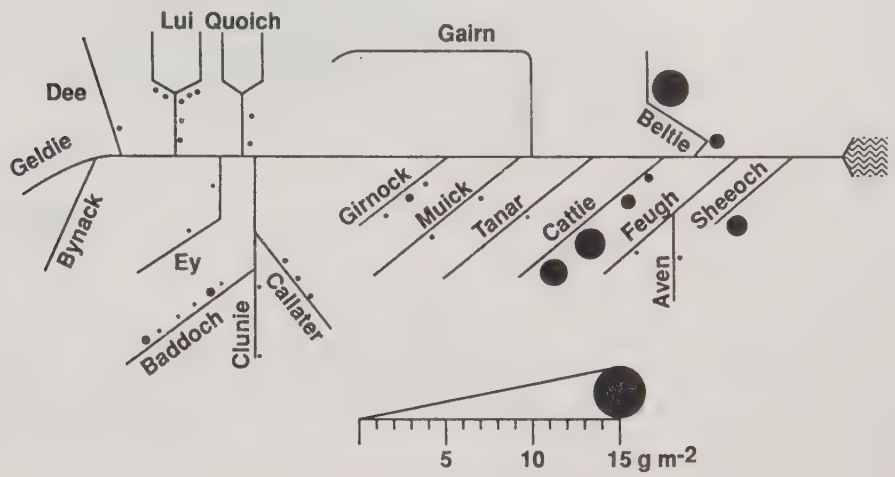

Figure 4. **Biomass of trout in the River Dee system.**

Areas of high juvenile salmon densities

In the Cattie Burn, one of the more productive streams, juvenile salmon occupy about 7.5km of stream (Fig. 5). Spawning sites are available over most of its length. Large numbers of 0+ salmon are present but the numbers of 1+ salmon decline rapidly after June. A likely explanation for this is migration into the main river particularly from the lower part of the stream. Numbers of 0+ salmon were similar in two years of study. The density of 0+ salmon in September 1988 was 1.3 m^{-2} whilst in September 1989 it was 1.0 m^{-2}.

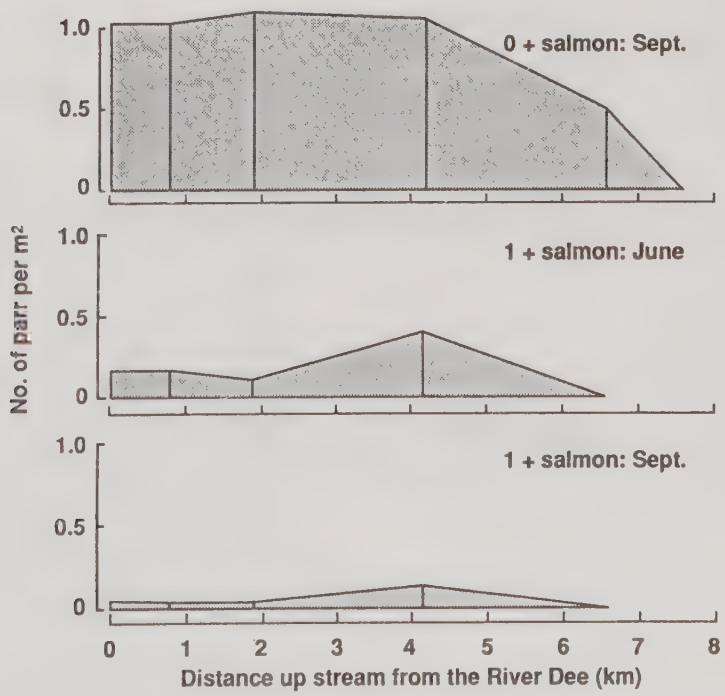

Figure 5. **The distribution of parr in the Cattie Burn during 1989.**

The main spawning grounds in the Baddoch Burn lie between 1 and 2.8km up stream of the junction with the Clunie Burn. The distribution of the juvenile salmon (Fig. 6) indicates that, by September, 0 + salmon are still closely associated with this area. However, this is not true of the older age classes which tend to be dispersed down stream of the spawning area. Juveniles over two years of age are more common in the areas above and below the spawning ground. Salmon stocks do not extend beyond a waterfall approximately 6 km up stream from the junction. The maximum density of 0 + salmon in September 1988 was $1.3m^{-2}$ whilst in 1989 it was $0.8m^{-2}$. However, year to year variation in 0 + densities by a factor of two is not unusual.

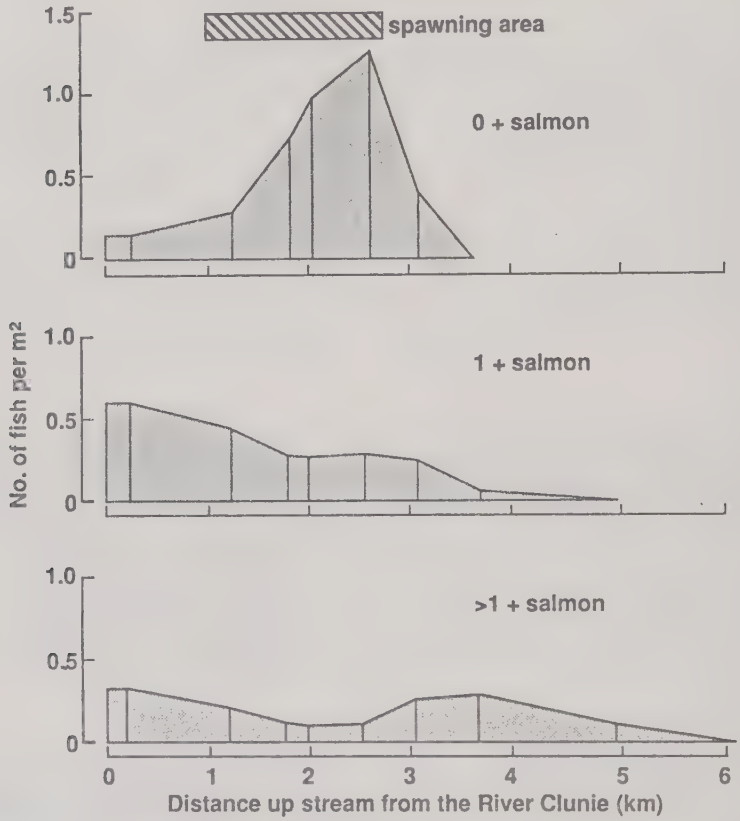

Figure 6. **The distribution of parr during September (1988) in the Baddoch Burn.**

The Callater Burn, with suitable spawning grounds between 2km and 6km up stream from the junction with the Clunie (Fig. 7), contained more extensive stocks of salmon parr of all age classes. Only 0 + salmon were observed at the top section immediately above Loch Callater, indicating more salmon production up stream of the area surveyed.

In the River Gairn, areas suitable for salmon spawning were present over most of the 24km of stream sampled (Fig. 8). There was every indication from the 0 + densities that good spawning extended beyond this point.The density of older year classes was slightly higher down stream, which perhaps indicates a possible movement in that direction. The densities of 0 + salmon during 1989 were similar to those of the previous year.

The Geldie, Bynack and in particular the Ey Burn, entering the top of the main river from the south and west, hold good stocks of salmon parr. In the Ey Burn, the densities of 0 + salmon reach $1.5m^{-2}$ over the spawning grounds in the middle region of the stream. In this stream, only 1 + salmon were found at a point 9.4 km up stream from the River Dee.

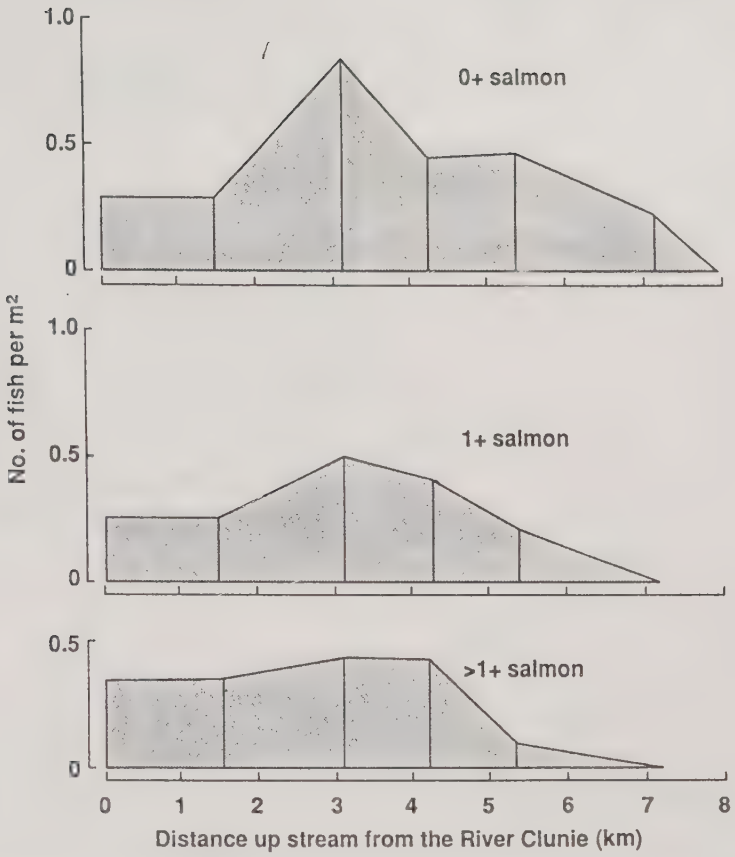

Figure 7. **The distribution of parr during August (1988) in the Callater Burn.**

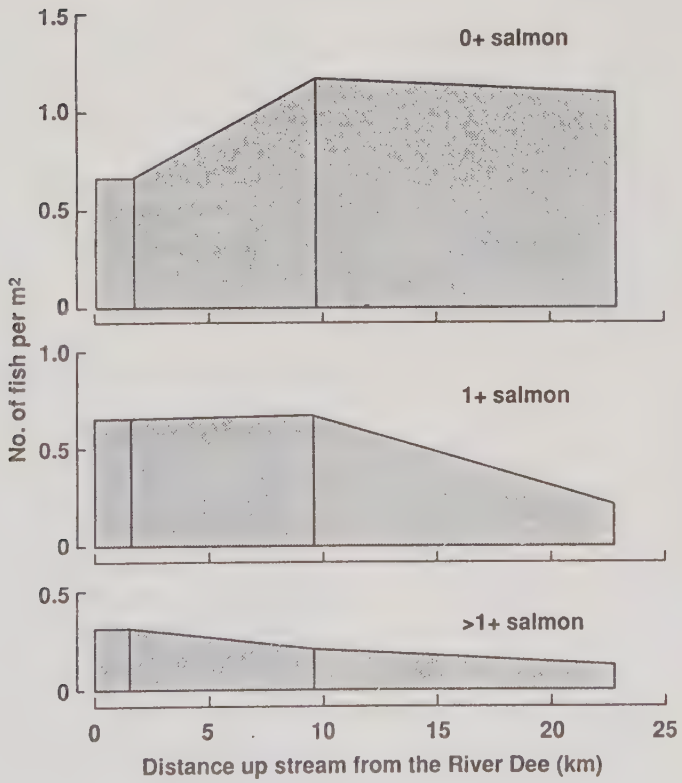

Figure 8. **The distribution of parr during September (1988) in the River Gairn.**

Areas of low juvenile salmon densities

Low biomasses were observed in two areas. In surveys carried out during May and June 1988, the upper half of the Beltie Burn contained low densities of all age classes of salmon. During the 1989 survey, low densities of salmon were also observed in tributaries joining the main river from the north above Braemar.

In the Beltie Burn, the distribution may be related to an intermediate area of the stream which has been canalised in order to drain agricultural land. Here the gravel bed has been removed and replaced with mud and silt. Figure 9 shows the distribution of salmon and trout in the Beltie Burn during the May 1988 survey. The areas of canalisation are indicated. The low 1+ salmon densities in the canalised sections can be seen clearly. The low numbers present above 10km indicate the possibility that access for adult salmon is restricted by modifications to the stream course. Numbers of 1+ trout can be seen to increase with distance up stream. However, the trout population density at lower altitudes may also be influenced by the canalisation, but to a lesser extent than salmon.

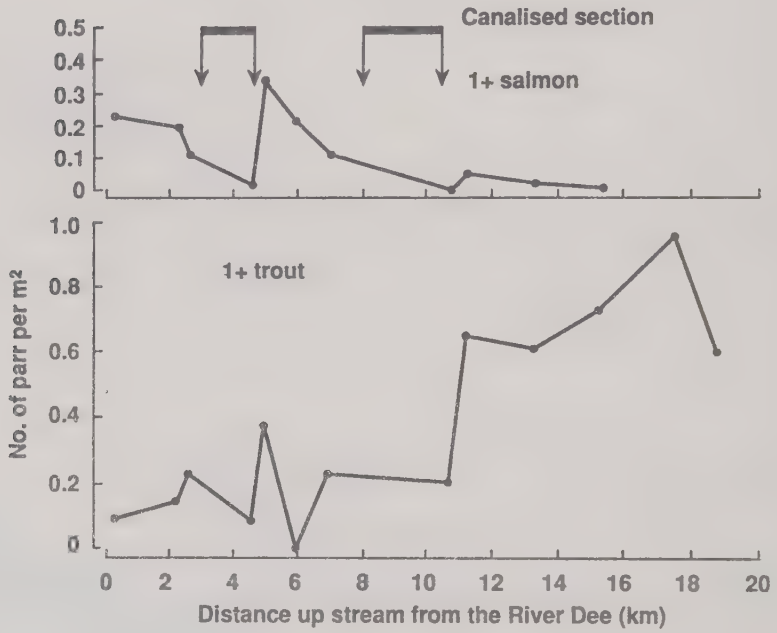

Figure 9. **The distribution of salmon and trout during May and June (1988) in the Beltie Burn.**

Densities of salmon in the streams joining the main river from the north above Braemar were low. The Lui Water (Fig. 10) was thought to be devoid of salmon because of an impassable waterfall (Shearer, 1961). A previous survey carried out between 1983 and 1985 indicated that the stream contained only trout (B.R.S. Morrison, pers. comm.). In the present survey, it was found to contain very low densities of juvenile salmon (max 19 0+ fish 100 m^{-2} in August) during 1990 compared with 104 fish $100m^{-2}$ observed in the Baddoch Burn in September of the same year. It seems that the numbers of juveniles present varies from year to year depending on the number of adults successfully ascending the waterfall. Samples from the Quoich above and below the falls suggest that salmon densities would be similar to those found in the Lui during that year. Only two salmon parr were found at the head waters of the Dee about 1km up stream of the junction with the Geldie Burn, though no physical barrier was present.

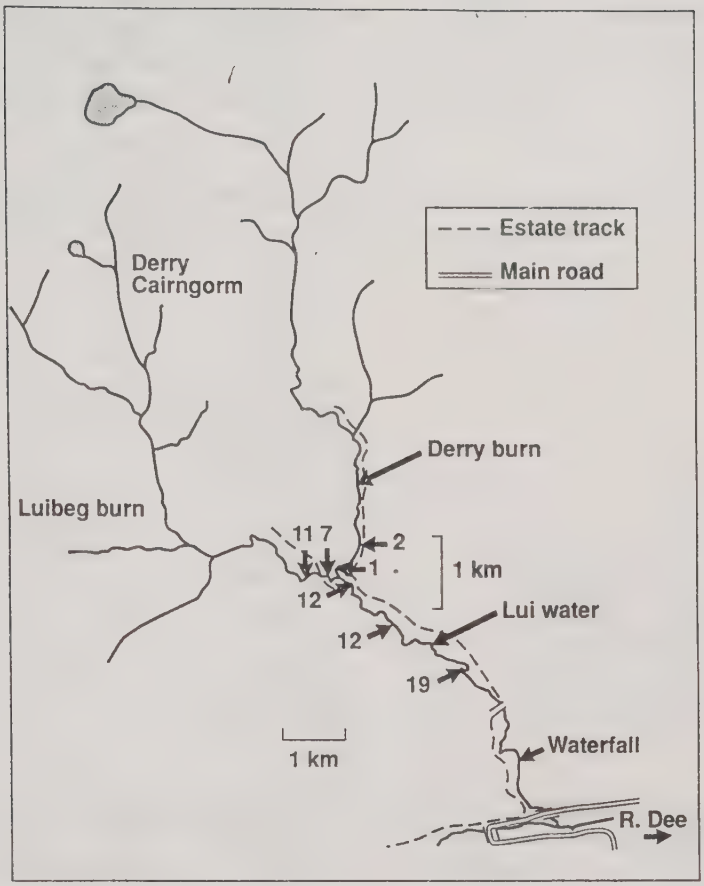

Figure 10. **The distribution of 0+ salmon of wild origin (numbers per 100 m^2) in the Lui Water during August 1990.**

Growth Rate

In view of the large altitude range covered by the sample sites, it is not surprising that a wide range of growth rates was observed. Figure 11 illustrates the growth in length of 1+ salmon over the period May to September in five of the streams. Fish mean length is clearly related to altitude. Salmon aged 1+ were chosen to illustrate this relationship because their growth can be followed over a longer period in the year than can that of 0+ salmon as it is difficult to differentiate anatomically between 0+ salmon and trout before mid-July. The Beltie, Cattie and Aven have a site altitude range of between 57 and 225m whilst, in the Baddoch and Gairn, sites ranged in altitude from 240 to 460m. To illustrate this further, the mean lengths of 1+ salmon from 13 sites between 18 July and 5 August 1988 were plotted against altitude (Fig. 12, Table II). From the values in the table, it was calculated that 61% (R^2 = 0.611) of the variation in length can be accounted for by altitude (Table III).

Table II

Length and weight of salmon caught between 18 July and 5 August in relation to altitude and water chemistry during 1988. Values for alkalinity, conductivity and nitrate concentration are average values from three water samples

Stream	Salmon 1+		Altitude (m)	Alkalinity (μeq l^{-1})	Conductivity (micro siemens)	Nitrate (μeq l^{-1})
	length (mm)	weight (g)				
Clunie 1	71.3	3.63	480	351	56	3.5
Clunie 2	69.9	3.37	410	351	56	3.5
Baddoch 1	68.7	3.21	450	323	49	3.0
Baddoch 3	60.6	2.13	435	334	49	3.0
Baddoch 5	61.4	2.23	430	330	50	3.5
Baddoch 7	66.9	2.94	415	330	50	3.5
Beltie 12	94.0	8.92	93	599	170	106.0
Beltie 17	93.4	8.73	75	599	170	106.0
Cattie 2	87.7	7.11	115	277	72	50.0
Cattie 3	90.1	7.77	93	277	72	50.0
Feugh 1	63.9	2.54	170	211	59	21.0
Aven	74.6	4.20	95	62	41	4.5
Sheeoch	83.0	5.94	93	328	102	45.0

Table III

Relationship between 1+ salmon length in July 1988 and both altitude and alkalinity

Factor	Coefficient	t-statistic	Proportion of variation explained (R^2)	Number of observations
1988 data				
Constant	89.99274	22.109		
Altitude	-0.05498	-4.155	0.611	13
1988 data				
Constant	76.93184	14.4356		
Altitude	-0.05337	-5.3015		
Alkalinity	0.03760	3.0093	0.796	13

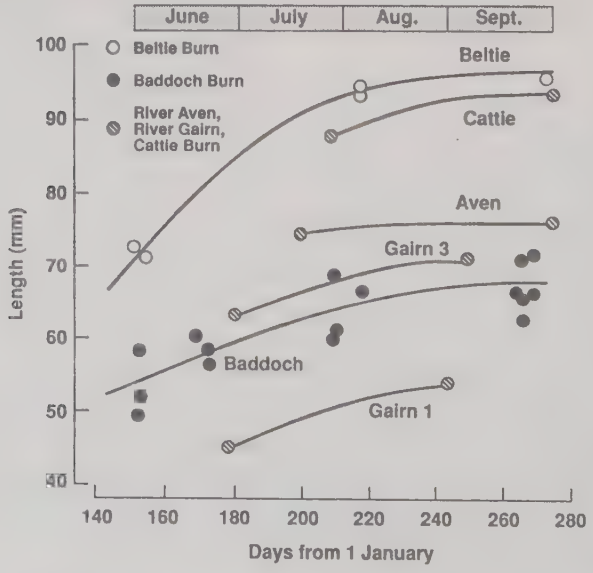

Figure 11.

The growth of 1+ salmon in five River Dee tributaries during the period May to September in 1988.

Some departures from the relationship with altitude can be observed. For example, Figure 11 shows the length of 1+ salmon in the Aven, at 95m in altitude, to be little greater than that found in Gairn site 3, at 240m, or in the Baddoch, at about 435m. They are also much smaller in Gairn site 1 than at a similar altitude on the Baddoch Burn. Moreover, Figure 12 shows that the fish from the Feugh, at 170m in altitude, were smaller than those from the Clunie and from those in some of the sites on the Baddoch Burn. Comparing all the sites between 93 and 170m in altitude, those from the Aven and the Feugh stand out clearly as containing small fish.

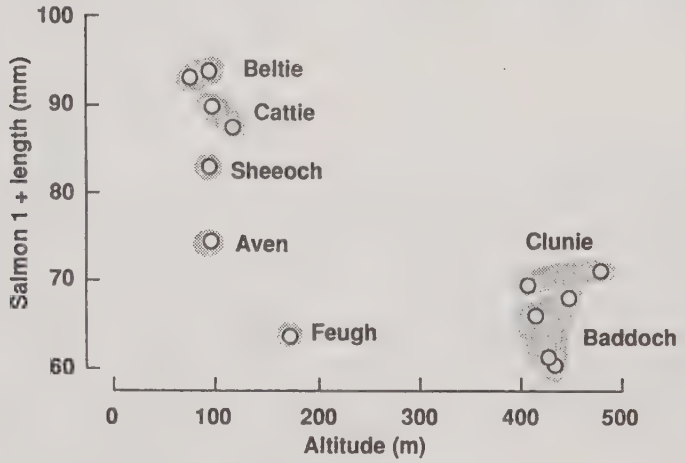

Figure 12. **The relationship between altitude and 1+ salmon length (mm) in seven streams over a period from the end of July to the beginning of August during 1988.**

It is normally assumed that the effect of altitude is really that of temperature. On the Dee river system, we have the opportunity to study temperature separately from water chemistry.

Stream Water Temperature and Growth

Temperature recorders were established on five tributaries, namely the Baddoch, Beltie and Cattie burns and the Rivers Gairn and Feugh. The results are given in Figures 13 and 14. Recorders at higher altitudes show lower temperatures during the winter but often show higher readings in the summer; for example, during the hot weather in June 1988 the temperature in the Baddoch Burn was up to 2.5° C higher than it was in the Beltie Burn.

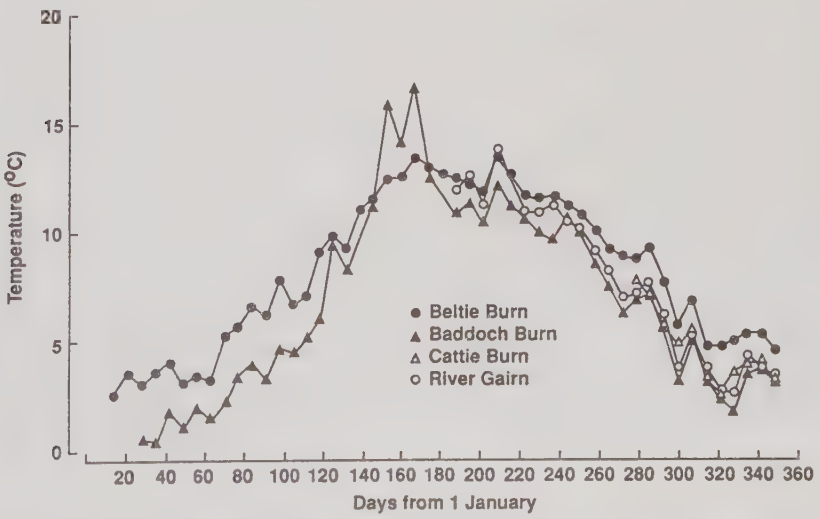

Figure 13. **Stream water temperatures in four tributaries of the River Dee system during 1988.**

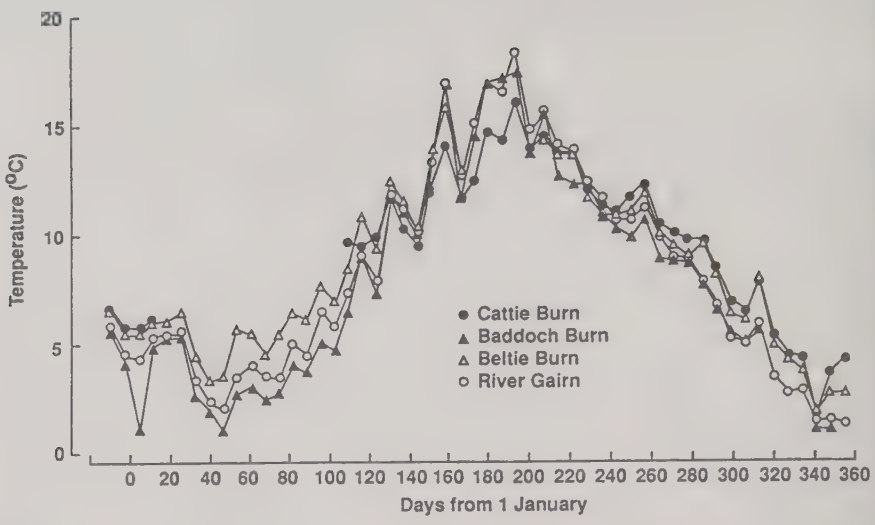

Figure 14. **Stream water temperatures in four tributaries of the River Dee system during 1989.**

Being cold-blooded animals, juvenile salmon exhibit growth rates closel related to the water temperature. Stream water temperature is indicative o the amount of solar energy falling on the stream catchment. Daily mea temperatures were calculated and a value for accumulated degree-days wa established. This is a measure of the energy absorbed by the stream wate over a selected period of time. Owing to the elevated summer wate temperature observed at high altitude sites, the degree-days accumulate during the fish growing season appear to bear little relationship to eithe altitude or fish length. However, it is possible that the length of the growin season is more important in determining fish size. Egglishaw and Shackle (1977) calculated a value of 622 degree-days to describe the amount o energy required to incubate salmon eggs from 1 December to emergence The date of emergence of fry can be calculated from this value. The result are presented in Table IV. Since the high altitude streams experience lowe winter and spring temperatures, the incubation period is extended, resultin in a shorter growing period. It was calculated that salmon fry emerged on o about 12 April in the Beltie Burn, resulting in a 171 day growing period up t 30 September. In the Baddoch, the fry did not emerge until 25 May reducing the growing period to 128 days. This delay in emergence ma explain why in September the 0+ salmon are 47% longer and the 1+ salmon 54% longer in the Beltie than in the Baddoch. However, the averag growth rates per day are much closer, those for 0+ being only 10%, an for 1+ only 16%, higher in the Beltie Burn. Fish size is therefore closel associated with the time of hatching and with the length of growing season.

Table IV **The relationship between 0+ and 1+ salmon length, altitude an temperature during 1989**

Stream	Altitude (m)	Accumulated degree-days 26 Apr-30 Sept	Estimated date of hatching*	Days of growth‡	Salmon 0+		Salmon 1+	
					length (mm)	growth per day (mm)	length (mm)	growth per day (mm)
Cattie	65	1,670	-	-	53.1		64.4	
Beltie	75	1,650	12 April	171	55.8	0.326	95.1	0.556
Feugh	130	1,740	-	-	52.8		86.1	
Baddoch	415	1,628	25 May	128	38.0	0.297	61.6	0.481

*Assuming 622 degree-days between 1 December and emergence

‡Days from emergence to 30 September

Effect of Water Chemistry on Growth

Figure 12 shows that 1+ salmon in low altitude streams (<170m in altitude) have a wide range of mean lengths. The fish in the Aven and Feugh have mean lengths comparable to those found in streams at high altitudes. It is unlikely that the fish size difference between these two streams and the Cattie Burn can be explained by temperature differences since the water temperature in May between 1544hr and 1602hr in the Cattie, Feugh and Aven, when temperatures were at their maximum, were 8.8, 9.0 and 9.3° C respectively. Therefore, factors other than altitude are affecting fish growth. In earlier extensive survey work in Scotland over the years 1984-1987, W.R. Gardiner (pers. comm.) showed that altitude (range 7 to 511m) and alkalinity (range 51 to 2,565 $\mu eq\ l^{-1}$) were useful explanatory factors for growth rates with the relationship:

Length = 53.1 - 0.036 altitude + 0.013 alkalinity

accounting for 81% of the observed variation in length reached by 0-group salmon by the end of their first growing season. Table II shows the water chemistry of the streams in the present intensive survey of the Dee system. This is closely related to surface geology and land use; for example the Beltie, Cattie and Sheeoch flow through cultivated land influenced by agricultural nitrate inputs, whilst the Feugh and the Aven are moorland sites. It was calculated from Table II that 80% (R^2 = 0.796) of the variation in 1+ salmon length can be explained by a combination of altitude and alkalinity (Table III) with the relationship:

Length = 76.9 - 0.053 altitude + 0.038 alkalinity.

Smolt Production

The final stage in the juvenile fresh water life of the Atlantic salmon is the smolt, ranging generally between 9 and 15cm in length. It is expected, therefore, that where the growth rate is slow, for example at higher altitude, more age classes are involved in producing smolts. Figure 15 shows the distribution of juvenile salmon lengths at five different altitudes. It can be seen that the numbers of year classes increase with altitude. Included in the figure are data from both the Feugh and the Aven. The former shows relatively larger numbers of 2+ fish compared with the Gairn which is 80 m higher in altitude. On the other hand the Aven shows the presence of a distinct 2+ group of fish, whilst in the Cattie at the same altitude, this group is reduced to one single individual at the chosen site.

On the assumption that salmon parr greater than 90mm in length in August and September are likely to migrate down stream during the autumn and the following spring, we can estimate, therefore, the number of parr likely to become smolts at that time from the parr densities, although some of these will become mature males during the autumn. Table V gives the estimated large parr numbers, ie parr >90mm in length, for five tributaries in 1988. Total numbers of large parr in each stream were calculated from electro-fishing results. Mortality rates have not been measured in the Dee tributaries but Egglishaw and Shackley (1977) calculated the daily instantaneous mortality rate (M) to be about 0.004 for 1+ salmon in the Shelligan Burn. Using this value of M, the numbers of large parr were calculated for the end of the growing season, which was assumed to be the end of September. Using the same value of M, the number of large parr expected to survive to the middle of the main smolt run the following year (1 May) was calculated.

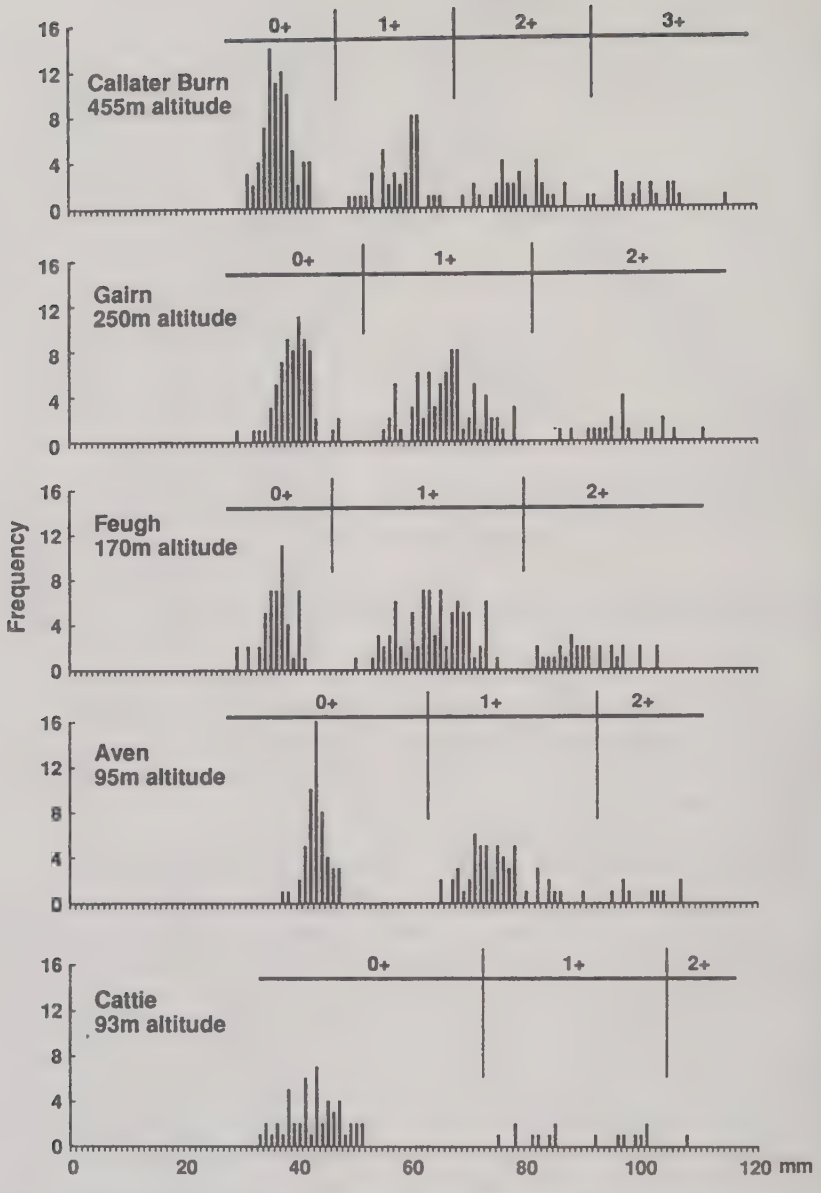

Figure 15. **Length distribution and age classification of juvenile salmon a different altitudes in the River Dee system.**

Table V **Estimate of smolt production from five tributaries and large par densities in seven tributaries of the River Dee**

Stream	Altitude	Highest number of parr >90 mm per 100m²	Number of 1+ salmon >90 mm long per stream in August	Days to 30 Sept	Number of 1+ salmon >90 mm long per stream on 30 Sept	Days to 1 May	Number of "smolts" on 1 May
Baddoch	430	14.7		0	6,808	212	2,916
Callater	450	12 4	7,949	36	6,883	212	2,947
Gairn	330	12.5	51,528	30	45,701	212	19,572
Beltie	75	20.6	6,781	57	5,399	212	2,312
Cattie	115	4.6		0	1,027	212	440
Total					65,818		28,187
Aven	95	4 5					
Girnock	300	8.0					
Shelligan	150	22.0					

Table V also shows estimated maximum large parr densities at the end of the growing season in some additional streams. It can be seen that the tributaries in the geologically richer catchments such as the Callater Burn and the Baddoch Burn, contain 12 to 14 large parr $100m^{-2}$. The streams in poorer granite catchments such as the Girnock Burn give densities around eight $100m^{-2}$. At the eastern end of the system, at lower altitude and amongst cultivated land, the Beltie Burn contains as many as 20 large parr $100m^{-2}$. The large parr density for the Shelligan Burn is given for comparison as an example of a well stocked chemically rich stream. The low parr density in the Cattie Burn is more difficult to explain, and is discussed below.

Discussion

The purpose of this study was to establish the population size and distribution of juvenile salmon and trout within the River Dee tributaries. The degree to which growth rate was explained by environmental factors was also considered. In addition, it was intended to identify any areas where it might be possible to increase the number of parr and subsequent smolt production.

The study of the juvenile salmonids was comprehensive, covering 18 of the 25 main tributaries of the Dee and Feugh. The results indicate that the distribution of trout was largely confined to a few tributaries at the eastern end of the system. However, juvenile salmon were more widely distributed. In the areas where they were most common, the biomass of salmon was frequently within or close to the range of 4.6 to 9.2 gm^{-2} observed in the Shelligan Burn (Egglishaw and Shackley, 1977). The highest biomasses were generally found in streams draining catchments enriched by basic rocks or by agricultural input. Previous work by W.R. Gardiner (pers. comm.) during 1987 in the River Gairn and Beltie Burn indicated similar salmonid biomasses to those found in the current survey.

Some of the headwater streams, such as the Lui Water, the Quoich and the top end of the Dee above its junction with the Geldie, contained less than two 1+ or 2+ parr $100m^{-2}$ and so could benefit from restocking as defined by Egglishaw *et al.* (1984). As these streams have granite catchments, the possibility of acid flushes with a pH below 5.0 should be borne in mind as they can cause high egg mortality immediately prior to hatching. However, the use of fry rather than eggs should circumvent this problem. Such a stocking was carried out in the Lui Water system with encouraging results (Shackley *et al.*, in press). In the Lui the initial low salmon parr density is the result of waterfalls restricting upstream migration of adult salmon for spawning. Such a stocking programme would have to be repeated each year; this does not detract from the effectiveness of fry stocking programmes as they are easily carried out and would add to the smolt production of the Dee system.

It is difficult to give a similar recommendation for the upper River Dee above the junction with the Bynack. There are no barriers to adult access. The Bynack Burn is well stocked with juvenile salmon, yet the neighbouring section of the Dee contains few fish. It is possible either that severe acid flushes originating in the granite catchment in the headwaters of the River Dee prevent hatching, or that spawning is irregular in these headwater streams. Historic information would be required for valid comment on this aspect.

The environment has a very strong effect on growth rate and subsequent smolt production in the Dee as in other systems. Egglishaw and Shackley (1977) described the effect of temperature on growth rate in the Shelligan Burn using cumulative degree-days from 1 December to the end of the growing season on 15 September. These authors were aware, however, of the influence of the date of emergence and length of feeding season. Elliot (1975) showed that trout growth was at its maximum between 13 and 15°C

and that it declined to zero at 20°C. It is likely, therefore, that when stream temperature rises above 15°C juvenile salmon growth rate will also be reduced. This may explain, in part, the poor relationship between degree days accumulated over the growing season and fish size. Further investigation into the relationship between water temperature and growth in the Dee system is planned.

In addition to temperature, water chemistry also affected growth. Egglishaw (1965) showed that the mean catch of fresh water invertebrate fish food per sample was related to the bedrock type of the catchment. More were caught in streams influenced by limestone and sandstone than in streams draining granite catchments. Furthermore, the quantity of invertebrate material per unit of detritus increased with the concentration of calcium in the water. This relationship is attributed to higher rates of organic decomposition in stream water of richer chemistry. Increase in fish food availability results in better fish growth (Egglishaw, 1968, 1972). The water chemistry is further enriched by agricultural development, with inputs of nitrates supplying a further substrate for the decomposers. It is interesting to note the similarity in the coefficients for altitude and alkalinity in relation to 1+ salmon growth observed in the present report with those calculated in the earlier, unpublished, work by W.R. Gardiner in relation to 0+ salmon growth.

Smolt production is related to growth rate. Where the growth rate is slow fish tend to be older when they smolt. Since mortality is continuous, the greater the length of time spent in fresh water, the less is the chance of parr surviving to the smolt stage. The mortality rate at various stages of the life history of juvenile salmon has been calculated for the Shelligan Burn (Egglishaw and Shackley, 1977). The application of Shelligan mortality values to the large parr densities of the Dee tributaries produces realistic estimates of the smolt run but there is no obvious reason why mortality rates should be identical in all streams. It would be useful to establish the range of mortality rates to be found in different parts of the Dee system. The Cattie Burn is a case in point. Here, the smolt production is difficult to interpret from large parr densities in September. It is possible that the growth rate is so rapid that parr disappear from the lower parts of the stream during July because the Cattie Burn is small (3.5 to 4m wide) and may not provide suitable habitat to support large, fast growing fish. The cover for larger juvenile salmon may also be reduced owing to clogging of the bed by the high sand load typical of granite catchments (Shepherd 1979). This problem is probably exacerbated by agricultural and forestry activity.

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Summary

The distribution is recorded of juvenile salmonids in 18 of the 25 main tributaries of the River Dee system. Salmon densities were higher in the areas enriched by basic rocks and also in areas of agricultural development. Areas containing low densities were in the more granitic catchments at the western end, and in areas in and above agricultural drainage systems. Recommendations for improvements are given.

The length of 1+ salmon was observed to be related to altitude and to some aspect of water chemistry. Fish from low altitude granite catchments had mean lengths comparable with those in higher altitude, chemically-rich catchments.

Smolt production was estimated for a few tributaries from the densities of salmon parr >90mm fork length, measured in August and September during the previous year. The relationship between smolt production and the physical and chemical environment is discussed.

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APPENDIX List of salmon sites with locations and dimensions

Site	Altitude (m)	Grid ref	Area (m^2)	Length (m)	Mean width (m)
Clunie 1	480	NO146806	91.3	11.0	8.3
Clunie 2	415	NO137832	106.9	11.0	9.7
Ey Burn 1	498	NO084824	60.6	7.3	8.3
Ey Burn 2	470	NO093837	75.1	9.5	7.9
Ey Burn 3	435	NO093859	83.3	8.5	9.8
Baddoch C	595	NO103788	89.4	15.9	5.6
Baddoch B	540	NO111795	74.9	14.7	5.1
Baddoch A	460	NO122808	88.04	12.9	6.8
Baddoch 1	450	NO124812	97.8	10.0	9.8
Baddoch 2	445	NO126816	84.7	10.9	7.8
Baddoch 3	435	NO129819	123.9	12.0	10.3
Baddoch 4	435	NO130821	86.9	9.2	9.4
Baddoch 5	430	NO129825	88.2	12.2	7.2
Baddoch 7	415	NO134832	75.9	10.8	7.0
Callater 1	495	NO189835	137.6	12.2	11.3
Callater 2	490	NO175846	57.9	10.4	5.6
Callater 3	475	NO168852	124.1	13.9	8.9
Callater 4	455	NO163862	95.9	7.6	12.6
Callater 5	420	NO164875	89.8	6.4	14.0
Geldie 1	445	NN999069	79.2	11.0	7.2
Bynack 1	435	NO006865	66.6	9.0	7.4
Luibeg 1	428	NO036933	144.6	12.0	12.05
Luibeg 2	422	NO039933	92.4	12.0	7.7
Lui 3	418	NO041933	84.7	8.3	10.2
Lui 4	408	NO048927	79.9	9.3	8.6
Lui 5	405	NO059921	94.7	7.4	12.8
Derry 1	425	NO043937	80.4	12.0	6.7
Derry 2	420	NO040933	103.9	13.5	7.7
Dee 1	408	NO017885	72.0	8.0	9.0
Quoich 1	403	NO092924	108.8	9.8	11.1
Quoich 2	330	NO118909	96.03	9.9	9.7
Girnock 1	240	NO325957	79.9	11.8	6.8
Girnock 3	288	NO321936	97.8	14.0	7.0
Girnock 3A	310	NO313921	68.8	16.0	4.3
Girnock 4	320	NO310914	74.5	11.6	0.4
Gairn 1	440	NJ191021	84.9	6.5	13.1
Gairn 2	332	NJ290004	130.5	7.4	17.6
Gairn 3	240	NO347979	85.9	5.6	15.3
Beltie 1	225	NJ620073	45.0	30.0	1.5
Beltie 2	193	NJ614061	90.9	34.5	2.6
Beltie 3	165	NJ611045	82.1	21.0	3.9
Beltie 4	140	NJ607028	76.0	20.0	3.8
Beltie 5	117	NJ622015	66.5	20.0	3.3
Beltie 6	114	NJ623012	89.8	21.0	4.3
Beltie 10	105	NO653993	79.8	13.7	5.8
Beltie 11	98	NO663990	115.7	18.0	6.4
Beltie 12	93	NO666987	89.6	16.0	5.6
Beltie 13	90	NO662983	74.4	12.2	6.1
Beltie 16	80	NO651976	81.0	12.0	6.7
Beltie 17	75	NO653973	80.7	13.5	6.0
Beltie 19	57	NO669965	73.3	10.7	6.9
Cattie A	180	NO559939	92.5	50.0	1.9
Cattie 1	160	NO568943	66.7	17.2	3.88
Cattie 2	115	NO582954	95.6	28.0	3.4
Cattie 3	93	NO604959	98.5	25.0	3.94
Cattie 4	65	NO615961	87.5	17.5	5.0
Feugh B	240	NO524903	81.6	17.0	4.8
Feugh A	212	NO541806	98.1	18.5	5.3
Feugh 1	170	NO563907	108.3	9.2	11.8
Feugh 2	130	NO592916	75.5	6.6	11.4
Feugh 3	70	NO643922	117.2	10.4	11.3
Aven	95	NO636915	93.6	7.4	12.6
Sheeoch	93	NO756933	77.1	20.5	3.8

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